University of Hawaii Sea Level Center

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1. PROJECT SUMMARY

The University of Hawaii Sea Level Center (UHSLC) collects, processes, analyzes, and distributes tide gauge data from around the world in support of climate and oceanographic research. The UHSLC focuses on the collection of high frequency measurements that are available in near-real time usually via the Global Telecommunications System (GTS). The center complements the Permanent Service for Mean Sea Level (PSMSL), which is the primary archive for historic monthly-averaged time series of sea level. Data are provided to the UHSLC from ~ 450 stations maintained by 65 international agencies. In addition, the UHSLC directly assists host countries in the maintenance and operation of 60 stations. The UHSLC is an active contributor to the Intergovernmental Oceanographic Commission Global Sea Level Observing System (GLOSS), and participates in operational and scientific oversight through the GLOSS Group of Experts. The UHSLC is primarily concerned with the implementation of the Global Climate Observing System (GCOS) sea level network, a subset of GLOSS designated as being of high importance for climate research.

The UHSLC distributes near real-time and historic data directly from its host web site, http://uhslc.soest.hawaii.edu, through a dedicated OPeNDAP server, the Pacific Marine Environmental Laboratory Climate Data Portal, the National Ocean Partnership Program (NOPP) sponsored National Virtual Ocean Data System (NVODS) project, and the NOAA Observing Systems Architecture (NOSA) geospatial and geospatial metadata databases. The center also collaborates with NOAA's National Oceanographic Data Center (NODC) to maintain the Joint Archive for Sea Level (JASL), which is a quality assured database of hourly sea level from an expanded set of global stations.

UHSLC datasets are used in conjunction with operational numerical models, for the calibration of satellite altimeter data, the production of oceanographic products, and research on interannual to decadal climate fluctuations and short-term extreme events. UHSLC station data are made available directly to the Pacific Tsunami Warning Center and the Japanese Meteorological Agency for tsunami monitoring, as well as to various national tsunami warning agencies. Over the years the UHSLC has participated in national and international programs including NORPAX, TOGA, WOCE, GODAE and CLIVAR.

2. ACCOMPLISHMENTS

2.1. Tide Gauge Operations

The UHSLC assists with the operation and maintenance of 60 tide gauge stations in collaboration with local operators (Figure 1). All of these stations transmit data via the GOES, Meteosat, or GMT satellites. The transmission cycles have historically been between 1 to 3 hours of 2 to 6 minute averaged data; however, we are in the process of switching all stations over to 5 to 15 minute transmissions of 1 to 3 minute averages, with even higher rates at major tsunami generation zones. Of the 60 UHSLC stations, 48 contribute to the GLOSS Core network, and 46 to the GCOS network. 11 are equipped with co-located GPS, and 21 are within 5 km of a continuous GPS reference site. The UHSLC shares responsibility for the sites with local operators, which lowers our costs by reducing travel for our technicians while raising the reliability of the stations and the data quality. At most locations, on-site personnel perform regular maintenance, tide staff measurements, and provide security. UHSLC's role has been to provide spare parts as needed, to visit the sites on 1-3 year intervals to repair and upgrade components and to ensure the proper operation of the station, to trouble-shoot problems as they arise in coordination with local operators, and to quality assess the datasets. In the long-term, we provide training on station operation and maintenance with the aim of eventually transferring full responsibility of the station to local agencies.

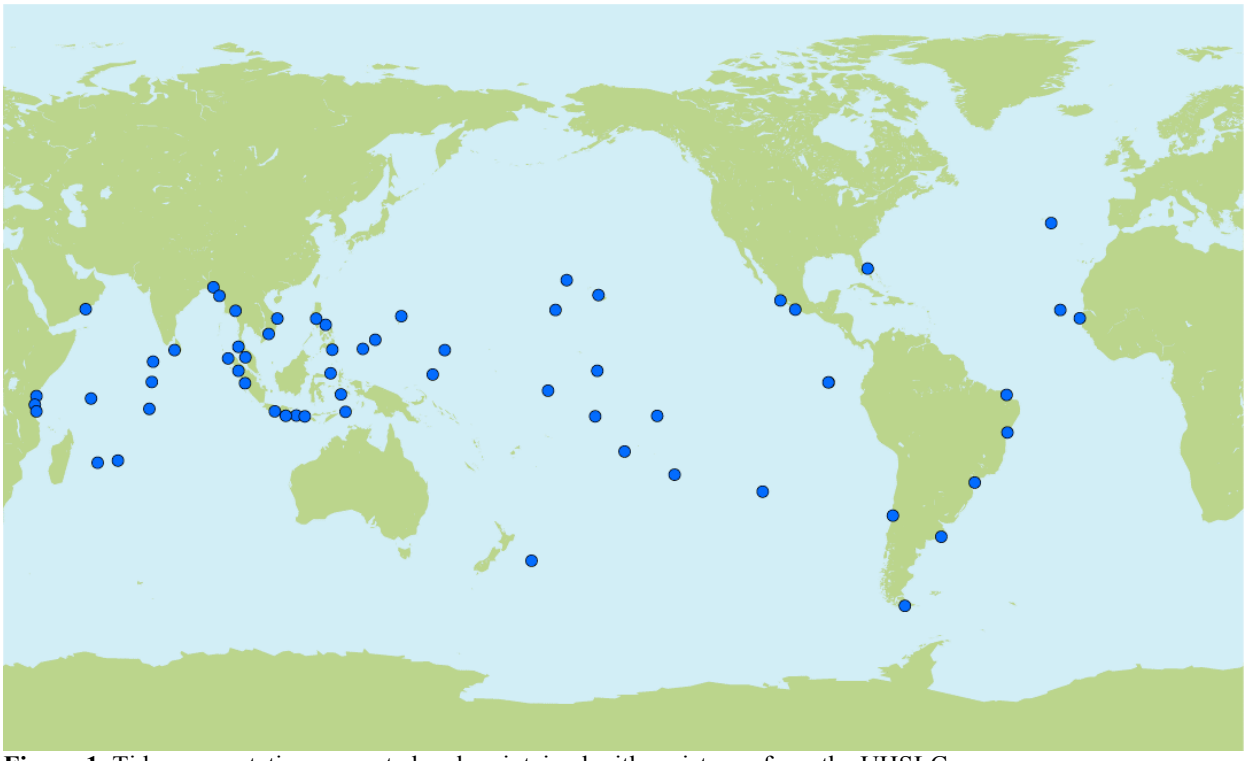

Figure 1. Tide gauge stations operated and maintained with assistance from the UHSLC.

New station installations and upgrades of existing OCO stations during FY2008 are listed in Table 1. The Intergovernmental Oceanographic Commission (IOC) provides supplemental funding for the maintenance of tsunami capable stations in the Indian Ocean. Our ability to tsunami upgraded stations at low costs to the co-sponsor was due to our core operational support provided by OCO. In turn, our involvement in this implementation benefited the aims of the global sea level network and OCO by ensuring that all stations are suitable for sea level monitoring as well as tsunami warning. All are equipped with open-air radar sensors, and most feature a backup float gauge or acoustic sensor, for stable and accurate long-term measurements. Most of these sites are either in the GLOSS Core Network or they will be proposed as new additions to the network at the next GLOSS meeting. In addition, we intend to recommend many of these sites as replacements for nearby GCOS stations that have a low probability of becoming operational.

Table 1. Station maintenance visits by UH technicians during FY2008. The stations in italics represent new installations.

Station	**Country**	**Date of Visit**	**Co-Sponsor**
Pointe La Rue	Seychelles	2007/12	IOC
Gan	Maldives	2007/12	
Hanimaadhoo	Maldives	2007/12	
Male	Maldives	2007/12	IOC
Johnston Island	USA	2008/1	
Baltra	Ecuador	2008/2	
Santa Cruz	Ecuador	2008/2	
Ponta Delgada	Portugal	2008/3	
Port Louis	Mauritius	2008/3	IOC
Rodrigues	Mauritius	2008/3	
Salvador	Brazil	2008/4	
Fortaleza	Brazil	2008/4	
Padang	Indonesia	2008/6	IOC
Sabang	Indonesia	2008/6	IOC
Sibolga	Indonesia	2008/6	
Cilicap	Indonesia	2008/6	
Benoa	Indonesia	2008/9	IOC
Langkawi	Malaysia	2008/9	IOC
Lembar	Indonesia	2008/9	
Bitung	Indonesia	2008/9	
Ambon	Indonesia	2008/9	
Saumlaki	Indonesia	2008/9	

2.2. Dataset Holdings

The Joint Archive for Sea Level (data latency: 1-2 years) is a collaborative effort between the National Oceanographic Data Center (NODC), the World Data Center-A for Oceanography, and the UHSLC. A NOAA Liaison officer supported by National Coastal Data Development Center (NCDDC) helps maintain the JASL. The JASL consists of a quality assured database of hourly sea level time series from stations around the world. We consider this to be our research quality database, complementary to the monthly averaged data maintained as PSMSL. In the past year,

the UHSLC increased its JASL holdings to 12,113 station-years, including 6,979 station-years at 234 GLOSS sites.

The UHSLC maintains a fast delivery database (data latency: 1 month) in support of various national and international programs (e.g., GODAE, CLIVAR, GLOSS, GCOS). To ensure active participation and coordination with the international community, the database has been designated by the IOC as a component of the GLOSS program. The fast delivery data are used extensively by the altimeter community for ongoing assessment and calibration of satellite altimeter datasets. In particular, fast delivery data are used for monitoring the latest JASON altimeter and for the tie between JASON, TOPEX/Poseidon, ERS, and GEOSAT satellites. The fast delivery sea level dataset now includes 239 stations, 210 of which are located at GLOSS sites, and 127 at GCOS sites.

We consider a fully operational network to have near real-time reporting capability. We post the most recent 5 days of data from 186 stations as part of our near-real time website (http://ilikai.soest.hawaii.edu/RSL/). At most of these sites, the data are also available for direct download. Real-time data are received via a number of transmission channels. For example, data from UHSLC operated stations are received at the data center within minutes of transmission using the geostationary meteorological satellite system and the GTS. Data from the U.K. stations are received via email and updated within hours of transmission. NOAA CO-OPS data are obtained via the GTS and a backup download from their web site. Data from Chile and other countries that use the GOES are acquired via the GTS and also downloaded from the GOES web site.

As part of the JCOMM SLP-Pac, the UHSLC operates a Specialized Oceanographic Center that produces sea surface topography maps (monthly) and diagnostic time series (quarterly) for the Pacific Ocean. This activity is a continuation of one of the earliest examples of operational oceanography. The analysis includes comparisons of tide gauge and altimeter sea surface elevations that are available at our web site (http://ilikai.soest.hawaii.edu/uhslc/products.html).

The center produces CD-ROMs that mirror the UHSLC web site. These CDs are distributed with the JASL annual data report, shared with all data originators, and sent to other users upon request. Over 100 were distributed again last year.

2.3. GCOS Network Status

The UHSLC is working with GLOSS and international partners to bring the 170 stations in the GCOS network into full operational mode, which means having all stations report high quality data in near-real time, with the majority of stations having vertical datum control via GPS or DORIS. The status of the GCOS network is summarized in Figure 2. In the past year, we've added approximately 17 new GCOS stations into the near-real time data stream, so that 60% of the network is at that capability (72% are at Fast Delivery status or better). We estimate that 77 of the GCOS stations have nearby (< 10 km) GPS or DORIS platforms. Immediate implementation plans for the GCOS network are described in the FY2009 work plan.

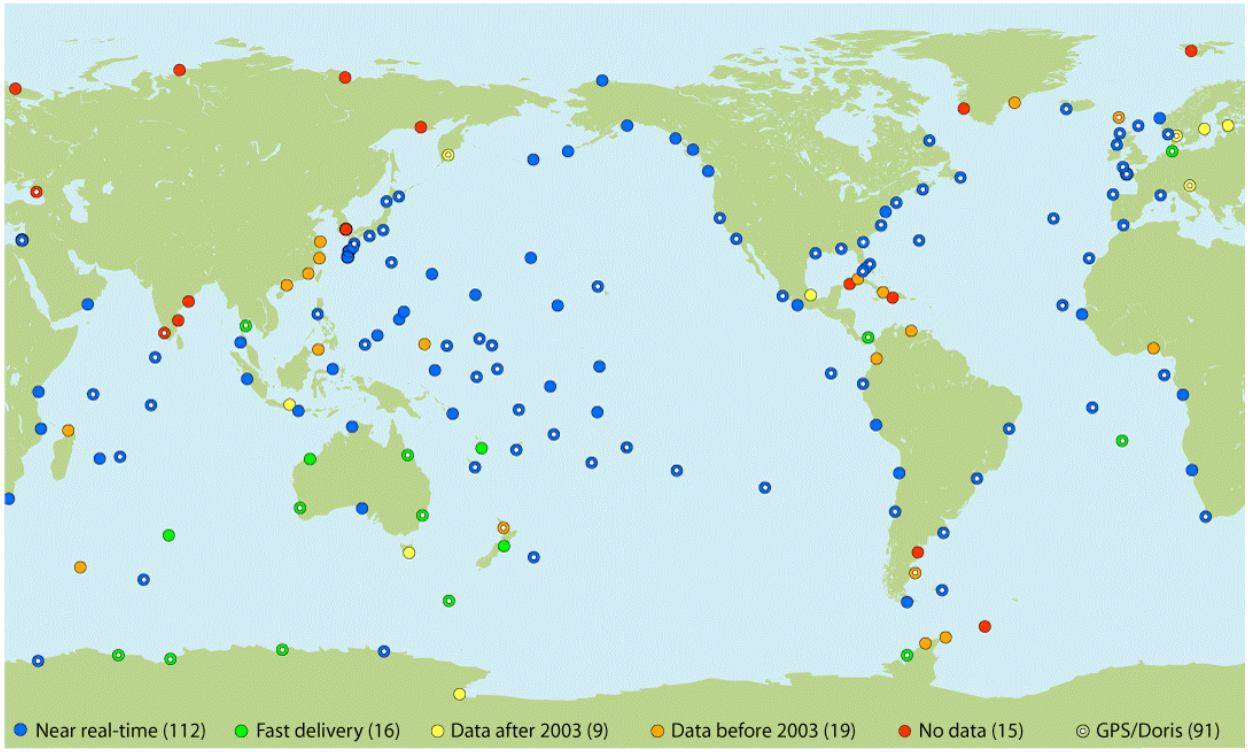

Figure 2. Summary of GCOS station data availability at UHSLC as of November 2008. The data must be sampled at one hour period or shorter. "Near real-time" are typically received within 1 hour, "Fast delivery" within 4-6 weeks.

2.4. Research Highlights

Research during FY08 focused on annual reporting of sea level, extreme events, and sea level rise estimates.

We completed a study documenting the relative importance of storms and tides in determining extreme water levels at tide gauges. Hourly time series from 157 tide gauge stations were used to specify global patterns of extreme coastal water levels, defined as values that exceed the 98 percentile of daily maximum hourly data above the annual mean level or each station, the extreme water levels were separated into tidal and non-tidal residual components using least squares fitting. Annual averages of the extremes and their tidal and residual components were used to define locations where high water levels are determined primarily by the tides (30% of all stations), by storms and other non-tidal processes (27%), and a mix of tides and storms (43%). The resulting spatial patterns of the tidal and residual components were compared to global estimates of tidal range and storm activity.

Tide gauge data were used to document a recent increase in the rate of global sea level rise. Linear trends over 15 year time segments were computed for each tide gauge record, averaged over latitude bands, and combined in an area weighted global mean. The uncertainty of the global trend was specified as a sampling error plus a random vertical land motion component. Corrections for land motion were considered based on altimeter-tide gauge trend differences. The average global sea level trend prior to 1990 is 1.56 ± 0.67 mm/yr, in agreement with previous estimates of 20th century sea level rise. After 1990, the global trend increases steadily to a current rate of 3.43 ± 0.47 mm/yr, matching estimates obtained from satellite altimetry. The

trend increase is insensitive to the vertical land motion correction. The transition from pre- to post-1990 trends is distinct from decadal variations in global sea level, which have been reported in previous studies. The recent acceleration of global sea level is accounted for primarily by increased rates in the southern hemisphere. The sea level acceleration coincides with warming and freshening trends observed in the high to mid-latitude regions of the southern hemisphere oceans, suggesting that regional volume changes account for the acceleration.

We are in the final stages of specifying a global reference frame for determining vertical land motion at tide gauge locations. Michael Bevis at the Ohio State University is performing the global analyses of GPS time series, and UHSLC will compare these results to tide gauge rates. We intend to have maps of land rates at all available GCOS and GLOSS stations by the end of the coming year.

We took part in the fourth OCO contribution to the BAMS State of the Climate report, describing sea level patterns during 2007, and an update of global sea level rise estimates (Merrifield et al., 2008).

2.5. Conferences, Meetings, Expert Panels, and Working Groups

ADPC Regional Steering Committee meeting, ADPC Regional Technical Committee meeting. Bangkok, 24-26 January 2008

POL BGAN planning meeting, Liverpool, 12-14 February 2008

Meetings & workshop for ICG/IOTWS V, Putrajaya, 6 April - 10 April 2008

Instructor for Carribbean Training Course for Operators of Sea Level Stations, Mayaguez, 23 June - 27 June 6 2008

Second International Round Table Dialogue on Earthquake and Tsunami, Kota Kinabalu, 6 October - 9 October 2008

ICG/IOTWS WG2 planning, International Conference on Tsunami Warning, ICG/IOTWS WG2 Meeting, Denpasar, 11-15 November 2008

ADPC RIMES Regional Steering Committee meeting, ADPC RIMES Regional Technical Committee meeting, Bangkok, 24-26 November 2008

3. PUBLICATIONS AND REPORTS

Merrifield, M**.,** G.T. Mitchum**,** S. Gill and P. Woodworth, 2008: Sea Level *in* State of the Climate in 2007, Levinson, D. H., and J. H. Lawrimore, Eds., *Bull. Amer. Met. Soc.*, **89**, S1-S179, doi:10.1175/BAMS-89-7-StateoftheClimate.

Mitchum, G., S. Nerem, M.A. Merrifield and R. Gehrels, 2009: 20th Century Sea Level Change Estimates From Tide Gauges and Altimeters, Cambridge University Press (reviewed book chapter), in press.